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POTENTIALS OF CONTAINERS IN CREATING MODULAR ARCHITECTURAL SPACES

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Keywords: Container, Modular Architecture, Architectural Space, Container Architecture, Sustainability

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POTENTIALS OF CONTAINERS IN CREATING MODULAR ARCHITECTURAL SPACES

Abstract

Containers are currently considered as one of the inventive trends of framing architectural objects. Container architecture is defined as the type of architecture that is characterised by the usage of steel containers as a structural elements and architectural envelope that can be presented as a part of architecture or a function that an activity can happen in it. Due to the specific dimensions that the container has, architects tend to use it to obtain modularity in their projects and the modular design strategies refer to using the containers as a standard unit to carry out the process, these containers are not only considered as a modular unit in design basis, but it is also used because of its structural strength, cheap cost, fast construction, its variety to change the function inside and its durability. Unfortunately, people are not aware of the importance of this type of material that can be used to obtain sustainability and reduce pollution and recycle the materials. Therefore, this paper aims to explore the container architecture by identifying different ways of creating architecture spaces that hosts different functions and activities not only in micro view but also in macro which means in large scale. In order to achieve the mentioned aim, the paper will start by presenting a literature review based on desk research, highlighting the previous reading about solving the problem. As a conclusion, it is important to have a clear detail about the potentials of containers and their different usage in life.

Keywords

Container, Modular Architecture, Architectural Space, Container Architecture, Sustainability

1. INTRODUCTION:

Containers, as a definition, are a large metal boxes that have standard design and standard size which is basically used for the transport of goods by sea, road, or air. However, nowadays, in the contemporary architecture, containers are being recycled and modified to be used as a temporary space like an office, a house, or even a compound. The container architecture refers to the transformation of these containers that are used for transporting goods to a type of architecture, (Sun,2017) as shown in figure 1&2.



Fig.1: Stacked shipping containers form temporary pavilion in Shanxi, China, by People's Architecture Office
Source: Containers Architecture Reusing Shipping Containers



Fig.2: Containers of Hope (2011)

In 1950, Malcolm McLean developed the container and was firstly used for transport industry. The military helped McLean's inventions and also put the containers in terms of emergency shelters in 1960.

Over the years, people started using these containers as a temporary office on construction sites or as a place for the workers to stay in and rest. (Bremner-Gargiulo,2018)

In the 21st century, in 2006, the Californian Architect Peter DeMaria designed the first container home in United States which is known as the Redondo Beach House and since then the container buildings were appearing worldwide. (Aaron,2020)

Unfortunately, people are not aware of the importance of this type of material that can be used to obtain sustainability and reduce pollution and recycle the materials. The usage of the containers as a building material has many positives especially that the containers have a very long span due to their fundamental strength and also, they are eco-friendly material. Moreover, containers are modular, they have a standard width and height Measurements so that they provide modular elements that can be combined into a larger structure, (Radwan,2015) as shown in figure 3.

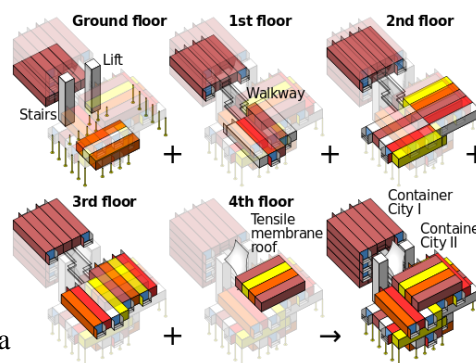


Fig.3: Illustration of the structure of Container City showing how the containers are stacked. Source: Containers Architecture Reusing Shipping Containers

Therefore, this paper aims to explore the container architecture by identifying different ways of creating architecture spaces that hosts different functions and activities not only in micro view but also in macro which means in large scale.

The main hypothesis of this research lies on the ability of containers in creating modular spaces due to their standard dimensions by showing different ways of using the containers in different types of building taking into consideration the sustainability.

This research is a qualitative type of work. The theoretical study will depend on scientific methodology, starting with a literature review, presenting definitions, theories, principles, approaches, and similar examples. And then, this information will be supported by previous readings, office work, extracting from updated references, and then the study will analyse this data in a scientific framework.

Whereas the analytical study will use reference readings, scanning official architecture websites and visiting sites (field work). In the mentioned site visits, the author will hold interviews, capture videos and photographs, hold discussions with inhabitants of the site, distribute questionnaires, observe features, and measuring dimensions.

This research will analyse two case studies, two provided locally and two internationally all while using specific parameters of analysis. After that, the research will compare between the two case studies to conclude the most important differences and commons.

These will shed light on containers and the pioneers involved in this field. This will be evaluated using the criteria formed previously. The conclusion will determine the success of fulfilling the architectural translation of the theory into the buildings and their spaces. (Youssof,2019)

2. LITERATURE REVIEW

2.1. Definition of Containers

“The essential element in architecture is the manipulation of space. it is essence which separates it from all other arts”.

Paul Rudolph

Source: Innovations in shaping the residential and retail buildings.
Functional and pro-environmental potential of shipping
containers in architecture

Container architecture Necessitate a form of architecture Futuristic in using steel maritime making containers the main design component. the containers appear internationally around 1956 in the transport facilities, where the cost is reducing, and the global eco-Crown has been allowed. Architecturally, the containers have adopted a solution for circulation horizontally and vertically according to the modular system. The new term was applied to the container in architecture (cargotecture). The containers create a shape and form that create an innovative approach to have an eco-friendly environment. In 1989, Phillip c. Clark, based on shipping modules, his first concepts and realisation saw to definition to patent application: “method for converting one or more steel shipping containers into a habitable building at a building site and the product thereof”. (Barbesiz,2017)

The module of the container has very high accessibility and ability. it is composed of framed of 4mm thickness steel, where also the exterior wall is curved metal. Besides, the floor has wood materials and plywood where the thickness is 28mm. It has a bolt lock. The containers could bear the atmospheric conditions, load, and transportation, and that according to the high quality of materials. The life assurance of containers in high conditions is about 30 years, but they are for marine containers are used for a maximum of 10 years. It has different sizes: standard, HC (high cube), PW (pallet wide), and open-top containers. these dimensions are ideal for the design of an office, housing, commercial, services, and a lot of functions, (Szefer,2017) as shown in figure 4.

Standard Containers

Suitable for every normal cargo

20' Dry Freight Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
5.910m 22'6 1/2"	2.340m 7'8"	2.380m 7'9 1/2"	2.286m 7'6"	2.276m 7'5 1/2"	1,900 kg 4,189 lbs
33.0 cu.m 1,165 cu. ft.					22,100 kg 48,721 lbs

40' Dry Freight Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
12.051m 39'6 1/2"	2.340m 7'8"	2.380m 7'9 1/2"	2.286m 7'6"	2.276m 7'5 1/2"	3,604 kg 7,936 lbs 3,630 kg (steel) 8,001 lbs (steel)
67.5 cu.m 2,377 cu. ft.					27,397 kg 60,401 lbs

High Cube Containers

Specifically for light, voluminous cargoes or those for excessive height (up to 2.67 m).

40' High Cube Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
12.051m 39'6 1/2"	2.340m 7'8 1/4"	2.684m 8'9 1/2"	2.340m 7'8"	2.584m 8'5 3/4"	2,900 kg 6,393 lbs
76.0 cu.m 2,684 cu. ft.					29,600 kg 65,256 lbs

45' High Cube Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
11.082m 44'6 1/2"	2.340m 7'8 1/4"	2.684m 8'10"	2.340m 7'8"	2.584m 8'5 3/4"	4,110 kg 9,061 lbs
85.7 cu.m 3,026 cu. ft.					28,390 kg 62,596 lbs

Open Top Containers

With Tarps (20' and 40') or no headtop (20').

Specifically for cargoes of excessive height, for loading from above (e.g., by crane), loading from door and thanks to removable doorheader.

20' Open Top Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
5.910m 44'6 1/2"	2.340m 7'8"	2.286m 7'6"	2.286m 7'6"	2.276m 7'5 1/2"	5,425m 17'9 1/2"
2.222m 7'3 1/2"					2,174 kg 4,793 lbs
31.6 cu.m 1,116 cu. ft.					21,826 kg 48,117 lbs

40' Open Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
12.043m 39'6"	2.338m 7'8"	2.272m 7'5 1/4"	2.279m 7'5 1/2"	2.272m 7'5 1/4"	11,585m 38' 7 1/4"
2.222m 7'3 1/2"					4,300 kg 9,480 lbs
64.0 cu.m 2,260 cu. ft.					26,181 kg 57,720 lbs

Flats

Specifically for heavy-lifts and overwidth cargoes.

Non-containerisable cargo can be accommodated on several Flats positioned side by side.

20' Flat Rack Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
5.207m 17'1 1/2"	2.403m 8'	2.327m 7'7 1/2"			2,330 kg 5,137 lbs
					21,670 kg 47,771 lbs

40' Flat Rack Container

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
11.820m 39'9 1/4"	2.148m 7'0 3/4"	2.095m 6'10 1/2"			5,260 kg 11,596 lbs
					25,220 kg 55,800 lbs

40' Collapsible Flat Rack

Maximum Inside Dimensions	Door Opening	Top Opening	Tare Weight	Cubic Capacity	Maximum Payload
L W H	W H	W	(kg/lbs)	(kg/lbs)	(kg/lbs)
12.048m 39'7 1/2"	2.126m 6'11 1/2"	2.043m 6'8 1/4"			5,800 kg 12,787 lbs
					29,200 kg 64,374 lbs

Fig.4: container standards Source: Containers Architecture Reusing Shipping Containers

2.2 Definition of Modular Architecture

The concept of modular design was produced based on standardization. The aim of modular design is to improve the degree of versatility, to reduce the variability and quantities of components in order to decrease the cost to have a more chances in productions. It was applied in the built-up of industry; moreover, it was widely applied in architecture gradually, (Martinez, 2013) as shown in table 1.

Moreover, the aims of modularity is to simplify the design process for the use of labour and resources efficiently, in order to get a reduce construction cycle, and to improve the quality of products to reduce the cost and maximise the economic benefits. Modular design have many specific definition , it usually refers to the division of a large system into several subsystems within a series of relations, and each subsystem can be replaced or combined with each other. It is also indicated that each module is a half self-control subsystem, the modules are related with each other in certain rules to interrelate and constitute a more complex system, and it contains two behaviours of division and concentration of the modules. (Scarsi, 2013)

Table 1: Narrow sense and broad sense of modular design

	Connotation	Denotation
Narrow sense	1. The system has a clear multistage modular hierarchies 2. Modules have compatibility on function and size	Modular production composed by different modules.
Broad Sense	1. Project is with a clear hierarchy 2. Modules are with generality and representativeness	Everything composed by typical generic units

Source: Modular System in Architecture 2013

2.3 Types of Container Buildings

2.3.1 Post-disaster or emergency settlements

These containers fulfil the requirements for emergency since it is prefabricated, easy to move, low cost, and can be easily repaired. They provide possibility for the victims as a safe place to stay in after an emergency and temporary settlement for a long term, as shown the example in figure 5.



Fig.1: ex container project, anywhere, japan Source: design boom

2.3.2 Residential buildings

The standard container offers feasibility for large scale residential purpose in short time and satisfies the basic requirements of spaces like safety, lightning, and ventilation and can be used as a low-income apartment and even a luxurious villa. (Shen,2019)

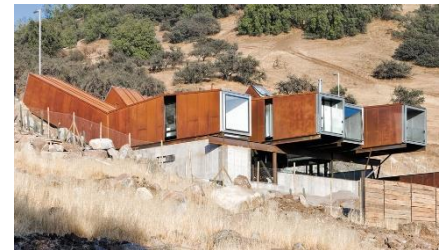


Fig.6: Caterpillar house in Los Trapenses source: Azure magazine

2.3.3 Leisure and education premises

Upon manufacturing most interior decorations in industries and constructing the remaining parts on the site, which will allow the settlement of the containers for leisure purpose in public places, and which will lead to the reduction of the influence on the local environment. moreover, it would be a solution for nurseries or schools, providing high quality learning environment in low-cost buildings as shown in figure 7.



Fig.2 APAP OpenSchool / LOT-EK Architecture & Design source: archdaily

2.3.4 Office premises

Mostly, these offices are used in the construction sites for the architects as an office to follow the work they want in the site and meet the client since upon construction, this kind of office construction is most applicable. In other words, it's a summation on both environmental protection measures and low construction cost that enables a high-quality office, (Copertaro,2019) as shown in figure 8.



Fig.3 : Sugoroku Office, Gifu, Japan Source: Inhabitat.com

2.3.5 Commercial premises

Container commercial buildings has been spreading widely all over the world and can be found simply in café kiosks, newspaper kiosks, coffee shops, fast food kiosks, commissaries, or even in bazaars, as shown in figure 9.



Fig.4: Marketing shopping place in Puma, Spain Source: trendhunter.com

2.3.6 Others

Containers can be used as public toilets or telephone booth. In conclusion containers can be transferred to any architectural space that the user wants (Zhang,2019)

2.4. First Usage of Containers in Architecture

For the first time, the shipping containers (box shape) was developed by Malcolm Mclean in 1952 and replace the break-bulk system and 58 containers are sailed. the first container vessel from the Port of Newark to Houston. The containers have developed and changes according to experiences in term of standards and functions. The global economic crises in 2009 had an important impact on the volume of international containers transport. Since 2010, it also apparent that a re-increase has taken place. In the 21st century, in 2006, the Californian Architect Peter DeMaria designed the first container home in United States which is known as the Redondo Beach House and since then the container buildings were appearing worldwide. (Aaron,2020)

2.5 Modules of Container Design

2.5.1. Dimensions

First, the geometry of the container is cuboid, it is permit for architecture to use this space for a function or activity. The dimensions of containers are standards. But it has many dimensions that are available in the market. The dimensions are for length (6.0-9.0-12.0 m), for height (2.4-2.55-2.7 m) and for width 2.4 m. The architect use for best proportions, the one which have a height 2.7 m to have a clearness 2.4 in the internal spaces. The container how has a length of 6 m, is named 20'HC, and the one that have a length of 12 is named 40'HC (Table 2). In addition, the 20'HC is more useful that 40'HC according to the best durability and cost. The difference between the internal and external dimensions comes the depth of members, from ceiling depth (25 mm), floor thickness (28 mm), and steel cross (127 mm), (Elrayies,2017) as shown in figure 10 & table 2.

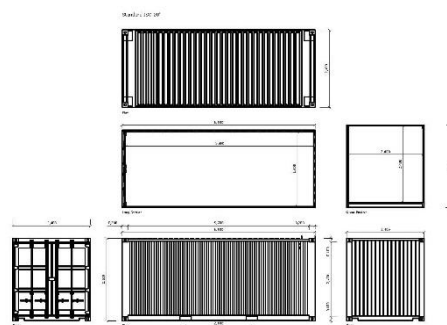


Fig.10: Residential drawing for Shipping Container
Shipping Container Primer (RSCP™)

Table 2: Size and dimensions of common ISO container

Model	Length (m)		Width (m)		Height (m)		Volume (m ³)	Empty Weight (kg)	Max gross mass (kg)	Net load (kg)
	In-ternal	Ex-ternal	In-ternal	Ex-ternal	In-ternal	Ex-ternal				
20'	5.898	6.058	2.352	2.438	2.385	2.591	33.1	2400	30480	28080
40'	12.032	12.192	2.352	2.438	2.385	2.591	67.5	4000	30480	26480
40' HC	12.032	12.192	2.352	2.438	2.698	2.896	76.2	4200	30480	26280
45' HC	13.556	13.716	2.352	2.438	2.698	2.896	86.1	4800	30480	25680

Source: thermal performance assessment of shipping container architecture

2.5.2 Structure and apertures

The steel used in for a container are designed for bearing the climate and weather changes. The wall, the ceiling and the edges of box are covered by a trapezoidal metal sheets, and the floor have a steel grid that is the support of wooden. The sheets have a thickness 2mm, and that the depth the formed by the steel is 25,30 and 50 mm, and that is depends the model of containers. Whenever the depth is big, the steel has more momentum and solidity. The corner is designed by steel rigid element that permit to support the load of the container and permit to connect the corners between it. On a small side, the door is

located, (Elrayies,2017) as shown in 11& 12.

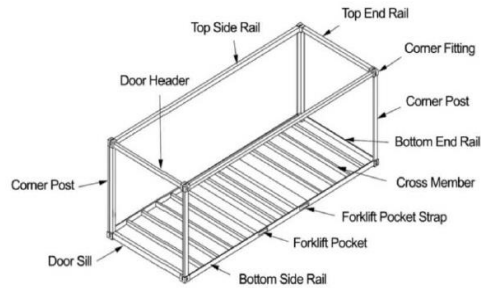


Fig.11; the core envelope of a typical 20 Iso SC
Source Thermal Performance Assessment of Shipping Container Architecture in Hot and Humid Climates

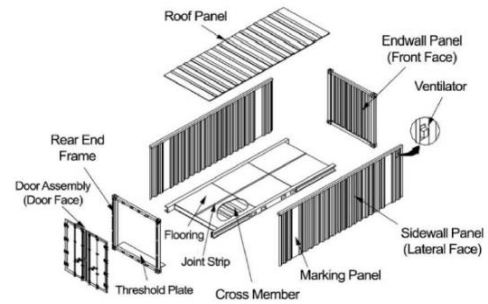


Fig.12: primary structural components for a typical 20 Iso
Source Thermal Performance Assessment of Shipping Container Architecture in Hot and Humid Climates

2.6 Methods to Execute Containers'

2.6.1 Foundation

The foundation is a typical slab on grey where the container is sitting on. The parameter of foundation wall is precast concrete or poured concrete. The contour was excavated and filled with gravel (for drainage). The precast slab is put on the foundation with a crane and tied together. The slab is isolated from water and thermal by DPC and thermal protection. The utilities (electricity, water, and sometime gaze line) are extended to foundation and connected to their central location. Back to the foundation wall are filled with soil and compacted and filled also respectively by the required and finishing materiel as shown in figure 13.

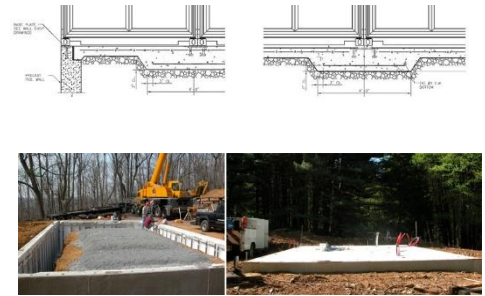


Fig.13: Residential drawing for Shipping Container
Source: Shipping Container Primer (RSCPT™)

2.6.2 Container modifications

The container has a single sheet of steel from all sides. The floor, the frames, the floor, the door, the roof, and the steel sheets compose the structural skin. They are rigid and strong to transfer the load from roof to beam to the columns, to the foundation to soil. This structural system allows to transform this void to an architecture space with the design what we want and need. But in opposite, when we modify any element of structure, it will be weak. So, the architect or engineer should study the deformation and give a solution to didn't have any problem after the modification. When the containers arrive to the site, they are move by the crane one to one and put it on their locations. And fix them, all corners are welded one with other from roof to foundations. All opening door and windows are framed by a steel section. The dimensions of opening should be measured to install the door and windows designed in their specific locations. All fixture will be installed with electricity, plumbing, hvac systems, insulation, and interior framing. Supertherm is a four-part high-performance ceramic layer which has an R-19 weight, applied to the shipping container steel top. The original 3/4-inch splice floor is fitted with a 1/2-inch splice floor. Cable channels are run around the walls and beams are secured with vertical supports. For inner partition walls the metal stubble and drywall are used. The current container walls are once isolated and are to be finished with a drywall, as shown in figure 14.

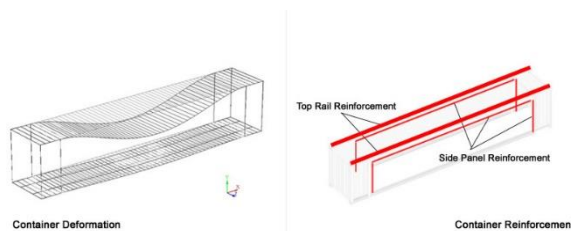


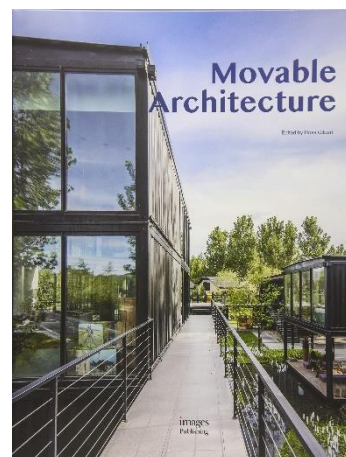
Fig.14: Residential drawing for Shipping Container
Source: Shipping Container Primer (RSCPT™)

2.7 Previous Readings

Several researchers have studied the topic of container and its potentials in creating modular spaces. In order to analyse the container architecture and know more about it, researchers have covered all the positives and the negatives of these types of materials used in architecture which permits us in choosing the best solutions and materials to solve different obstacles in architecture and modularity. Researchers studied and highlighted the use of containers in different building types.

According to Ross Gilbert in her book “Movable Architecture: A Design Guide to Container Reuse” published in 2018, the book features creative container architecture and focuses on their positives and negatives from a sustainable point of view inspired by architects and designers focusing on the requirements for energy-efficient sustainable architecture with a little carbon footprint. The book also explores different ways of using containers and how it can be renovated to create a contemporary housing unit and different other building types with environmentally friendly designs, low cost, and ease of mobility which will lead to the development of low carbon architecture. The book will analyse more than 40 container examples used in architecture with their design guidelines which will help the reader form a conclusion and have an overview of container architecture.

According to Salvador Solis Rizo in his book “Container House V2.0 – The Affordable and Sustainable Alternative: Plan /Design/ Execution” published in 2020, the main objective of this book was to understand how to plan, design and build using containers as an affordable and sustainable alternative that fits the need of the user and his budget. The author gave an overview of the history of container architecture and the current state of modular residence. Moreover, the reader will be able to know the different types of containers and their characteristics which will raise awareness about the structure and dimensions of a container



2.8 International Examples

2.8.1 Potter's lane apartments, midway city, CA, SVA architects 2016

The apartment building was made entirely from recycled shipping containers and transform them into housing units that are functional and aesthetically pleasing. It consists of 16 housing units each units size is 425 sf . these 16 studio apartments were constructed from 48 containers. The construction was based on modular architecture which was obtained due to the specific dimensions of the containers that were used for this project (Jones,2017)\



2.8.2 Whitaker studio's joshua tree residence, USA, 2016

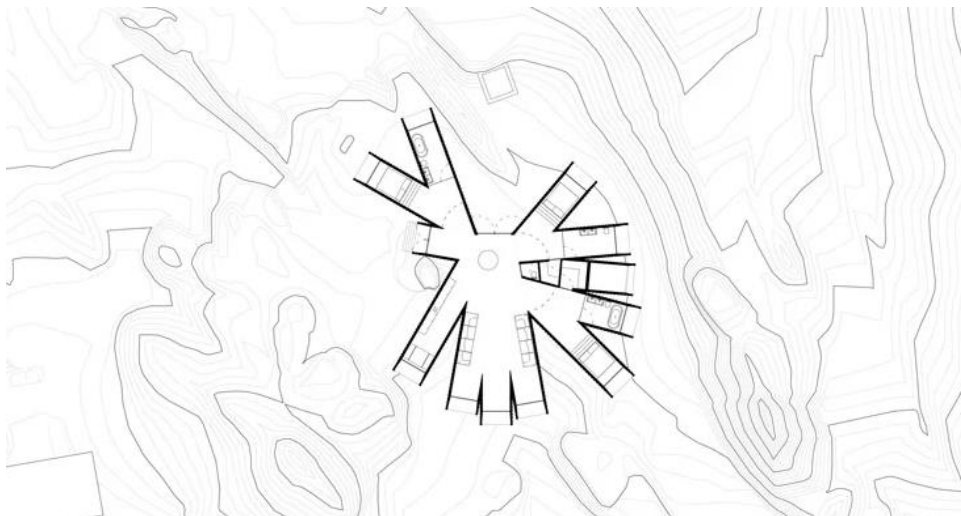




Fig.16: perspective of the building

Source: <https://www.designboom.com/architecture/whitaker-studio-joshua-tree-residence-california>

Many architects took the advantage of containers due to its flexibility and used them to create different types of spaces. Whitaker Studio used the containers as a modular building unit and created a working space that is beautiful, practical, and inspiring. The name of the residence was tree residence since the form that the container has formed is like a tree shape. Reusing these containers saved tons of steel and didn't cost much due to the recycling of the existing containers which lead to the idea of sustainability. (Staff,2017)

2.7 Parameters of Analysis

Based on the previous research, the deduced parameters of the advantages of container architecture are summarized in the following table

Table 3: Parameter of Analysis

Containers				
Strength	Sustainability	Durability	Climate change	Mobility
safety	Eco friendly	Maintenance	Weather	transportation
Container Architecture				
Structure	Sustainability	Maintenance	Cooling/heating	flexibility

These parameters must be referred to while investigating about the potentials of containers in creating modular architectural spaces

3. RESEARCH METHODOLOGY REFLECTING THE SUGGESTED PARAMETERS

The research is based on a qualitative type of work. The research is based on three research method; the inductive method, the analytic method; and comparative analytical method. The first one was used to gather data about the selected two case studies based on consulting a variety of sources. The second was used to analyse these data, providing figures and necessary drawings and diagrams to enhance explanation. The third method was a comparative analysis between the two case studies.

In this context, the study used the parameters, mentioned in table (3), to analyse the two case studies which were selected according to the following criteria:

- Diverse function and location
- Complete Projects
- Different scale.

3.1. Case Study One: “Urban Rigger”

- Function: Dormitory
- Location: Copenhagen
- Architects: BIG, Bjarke Ingels Architects
- Project Year: 2016
- Area: 7,319 sq. feet

Urban Rigger main concept was to solve the problem of the lack of accommodation for students by doing a floating dormitory made from shipping containers on top of a floating concrete pontoon to have 12 apartments at the port of Copenhagen. The concrete pontoon form has a basement which includes, storages for apartments, laundry room and technical rooms like ventilation system, batteries to store energy from the solar panels, water and heating pumps...) (Nodregio, 2018)



Fig.17: perspective for the building Source:

3.1.1. Parameter 1: structure

The containers are placed on a concrete floating base and are connected in a 6-pointed star model. A floating concrete is a solid figure made from reinforced concrete and an inner chain filled with a lightweight material like polystyrene. The structure consists of the containers itself with steel structure beams so that the containers will be connected to each other, (Ingels,2018) as shown in figure 18.

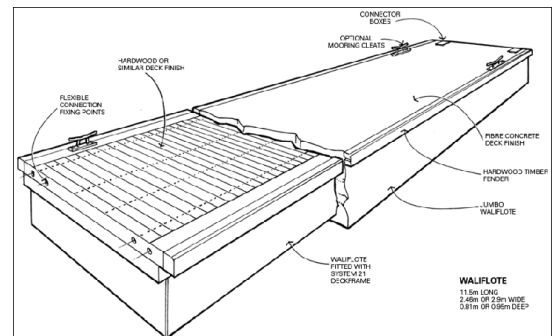


Fig.18: a detail for the structure Source: YACHT HARBOURS BY WALCON

3.1.2 Parameter 2: sustainability

According to different studies, there are many abundant shipping containers present in the port of Copenhagen, Ingels got an idea to transform these unused materials to a dorm that will solve the problem of using materials and moreover solve the problem of transportation which means the problem of air pollution. Moreover, they used different systems like photovoltaic sheets to obtain energy efficiency and a heating system and cooling system and provided the windows with sheets to consume the energy from the sun light (Nodregio, 2018)

3.1.3: Parameter 3: maintenance

Container architecture has its own type of maintenance, in Urban Rigger they got more challenging due to there presence near the ocean which will force them inspect the containers several times a year.

Urban Rigger is a temporary compound placed for students which have several specifications that should be fixed several times a year. And the most important part of the container that is checked every once in a while, is the roof of the container, (Katharine, 2019) as shown in figure 19.



Fig.19: a photo showing the maintenance Source: BIG

3.1.4 Parameter 4: cooling and heating

The containers present in the compound are illuminated by a large full height window that gives a panoramic view for the surrounding. The container sheets are thermally insulated by an air-gel developed by NASA, renewable source provide energy necessary for the operation of the building and the air conditioning of the interior spaces which is obtained by the heat pumps and cooling units installed in each container. In addition, all containers are equipped with hydronic radiant floor panels and a heat recovery ventilation system, (Sottosanti,2017) as shown in figure 20.

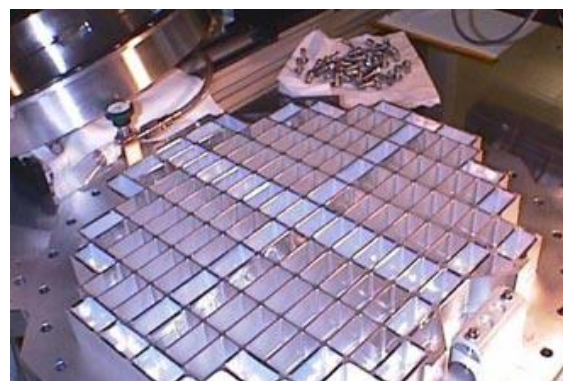


Fig.20: a picture showing an example of the air-gel by NASA Source: NASA official page

3.1.5: Parameter 5: flexibility

The standard size of container system which was used as a dormitory function reduced the cost of transportation through land, sea and air through a complex network of operators.

This system offered an extremely flexible type of building accommodation which is based on the composition of basic modules made from the shipping containers and can be connected to form a composition of a residence and other services for it, (Scottosanti,2017) as shown in figure 21.



Fig.21: panoramic view Source: Morten Jerichau

3.1.6 Architecture drawings

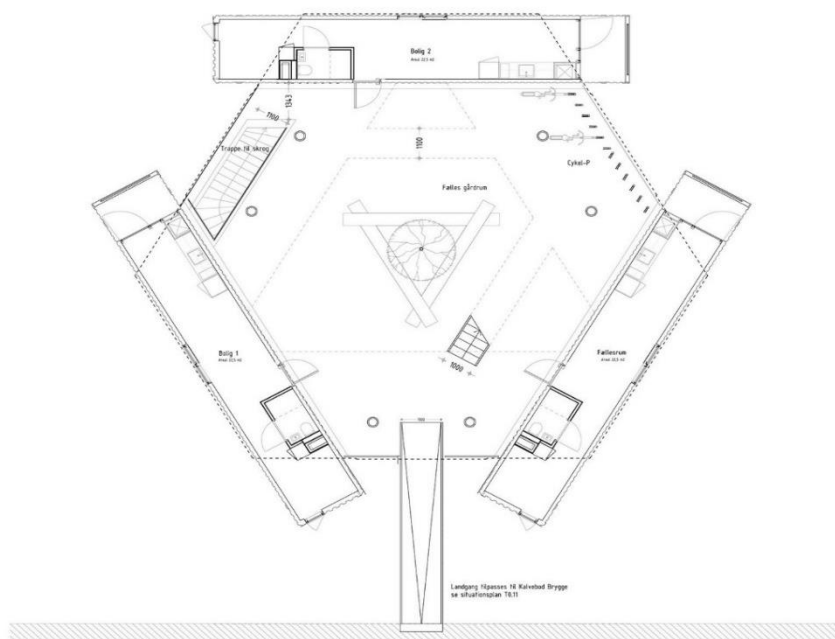


Fig.22: Ground Floor Plan Source: livingspace.net

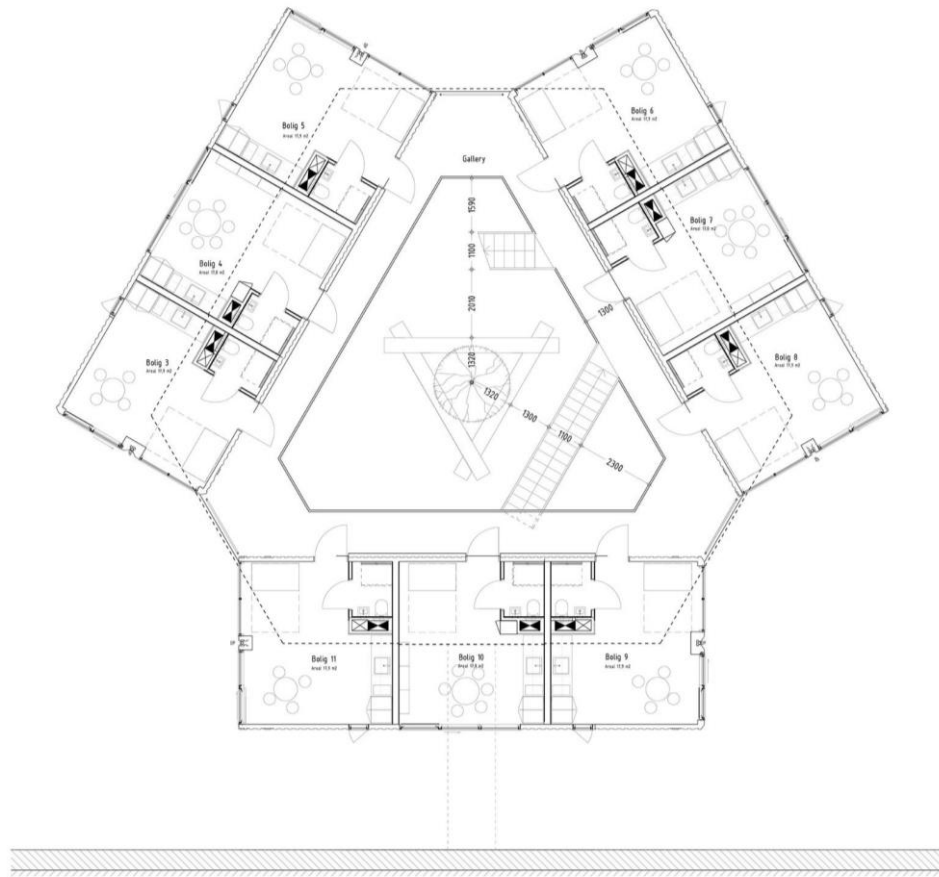


Fig.23: Second Floor Plan Source: livingspace.net

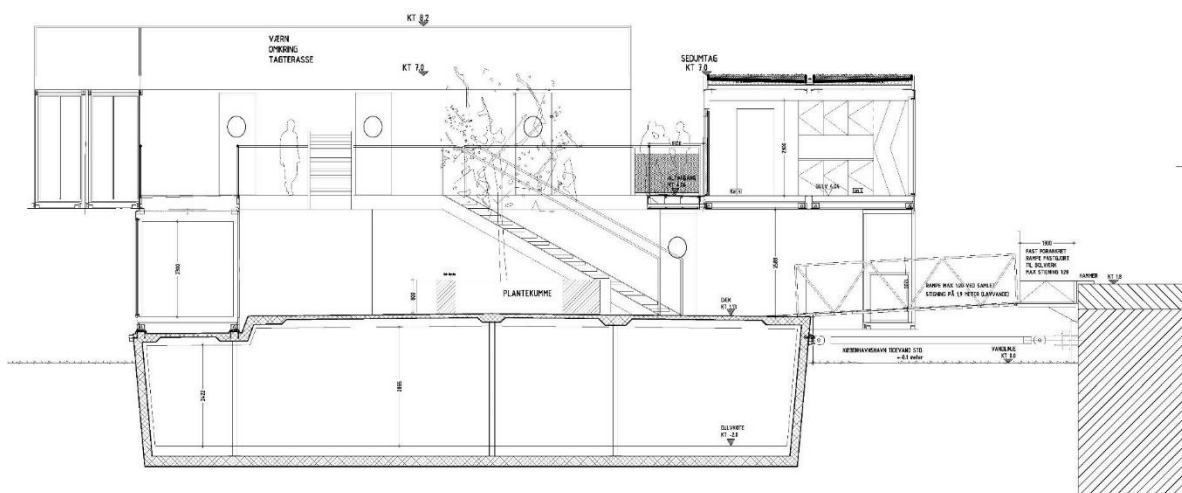


Fig.24: section Source: livingspace.net



Fig.25: perspective of the building Source: livingspace.net



Fig.26: thoughts for future about the compound Source:livingspaces.net

Table 4: Table of Parameters of Case Study 1

Containers				
Strength	Sustainability	Durability	Climate change	Mobility
safety	Eco friendly	Maintenance	Weather	transportation
Container Architecture				
Structure	Sustainability	Maintenance	Cooling/heating	flexibility

3.2 Case Study Two: “Box park Croydon”

- Function: Mall including cafes, restaurants, galleries, retails...
- Location: Croydon, United Kingdom
- Architects: BDP
- Project Year: 2016
- Area: 2,622 sqm

Box park is a two-story structure that was designed by 96 containers which formed a semi-enclosed market hall with units surrounding it like retail shops and restaurants. It has a covered seating area, 36 retails and have a place for events like music and performance or even some sports.



Fig.27: perspective of the building Source: Archdaily

3.2.1: Parameter one: structure

The center courtyard is covered for seating and events which is spanned by a steel frame roof canopy structure. It is clad with polycarbonate which allows natural lightening to penetrate the area below. The canopy is supported by twelve vertical columns measuring approximately 20mx20m, while the canopy is reinforced by several cross bracings which are placed between the main columns to add some extra security and stability. The steel structure stanchions for the canopy and the timber slippers which support the ground floor containers are held by the piles that are laid for structural support. Finally, the containers roof has its own steel framed structure, (Thanthrety, 2018) as shown in figure 28.

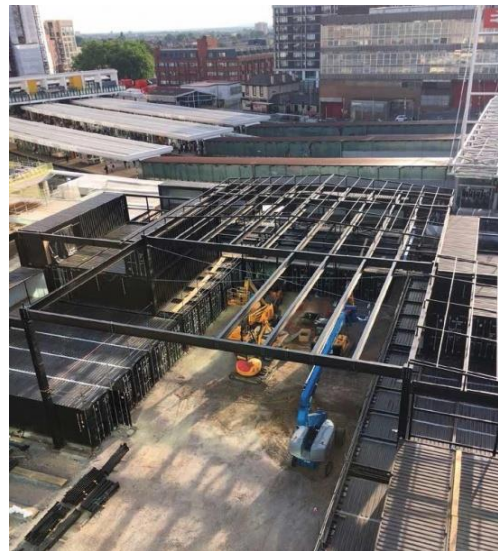


Fig.28: steel structure covering the containers Source: Steelconstruction.info

3.2.2 Parameter two: sustainability

In this case study study, sustainability was found in the reusage of the shipping container as a building with providing natural light during the day due to its open courtyard in the middle which led to the presence of natural lightening thus reduction of energy consumption in day.

3.2.3 Parameter three: maintenance

Container architecture has its own type of maintenance, in. the Box park, the presence of this huge steel structure skylight will lead to several obstacles which in fact should be maintained eventually several times, according to the containers, since there is a direct lightning, this will lead to rusting the container through time, but other than that, the container structure will remain as strong as it is

3.2.4 Parameter Four: Cooling Heating

The building contains several patio heaters in addition to air conditioners which is present near every seating area in the building. Moreover, the seats can be heated if needed in winter or if the user is cold, (Croydon, 2016) as shown in figure 29.



Fig.29: Indoor court supported with heating and cooling system Source: Archdaily

3.2.5 Parameter five: flexibility

the standard sizes of the containers that was used and the material used made it flexible enough to approach and know where u want to go next. Moreover, the modularity in choosing a standard dimension of the containers took an enrollment in the flexibility of the project.

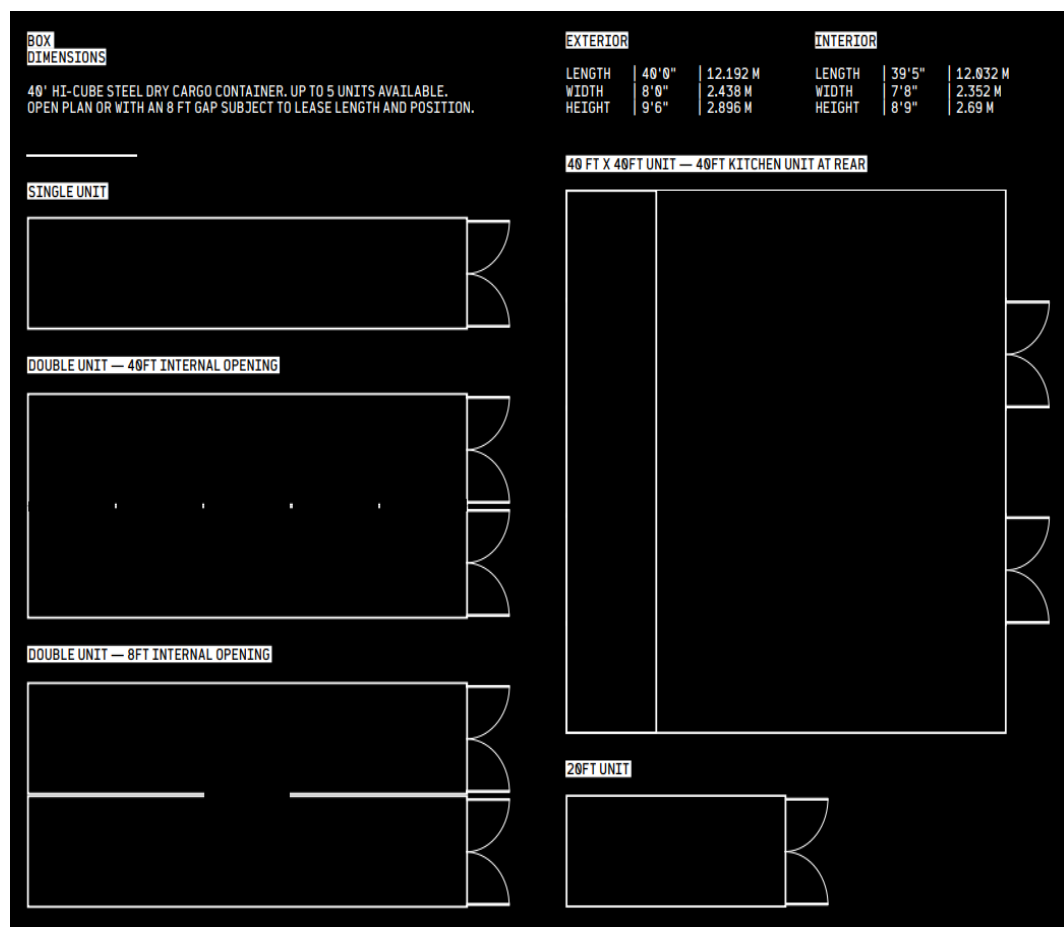


Fig.30: dimension of containers used in the compound Source: Box park Book

3.2.6 Architecture drawings

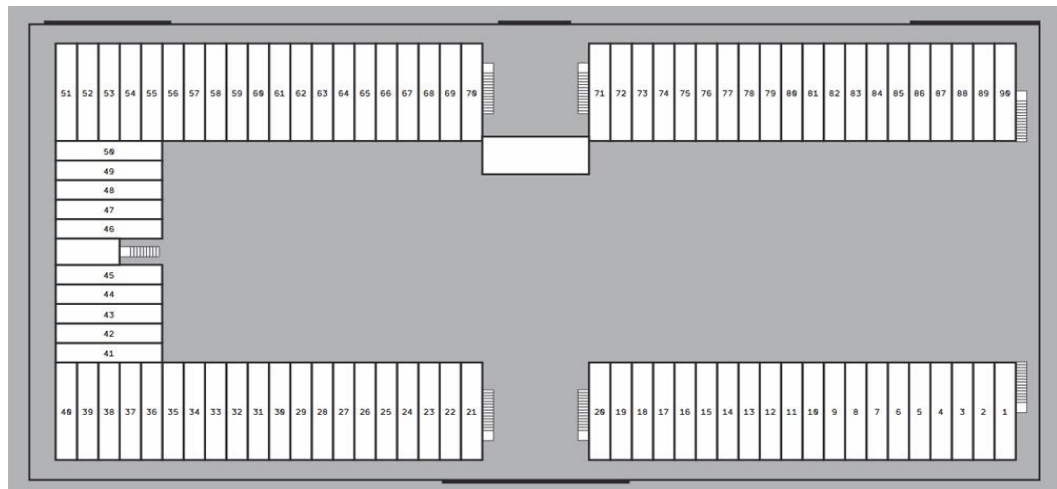


Fig.31: Ground Floor plan Layout Source:Deezen

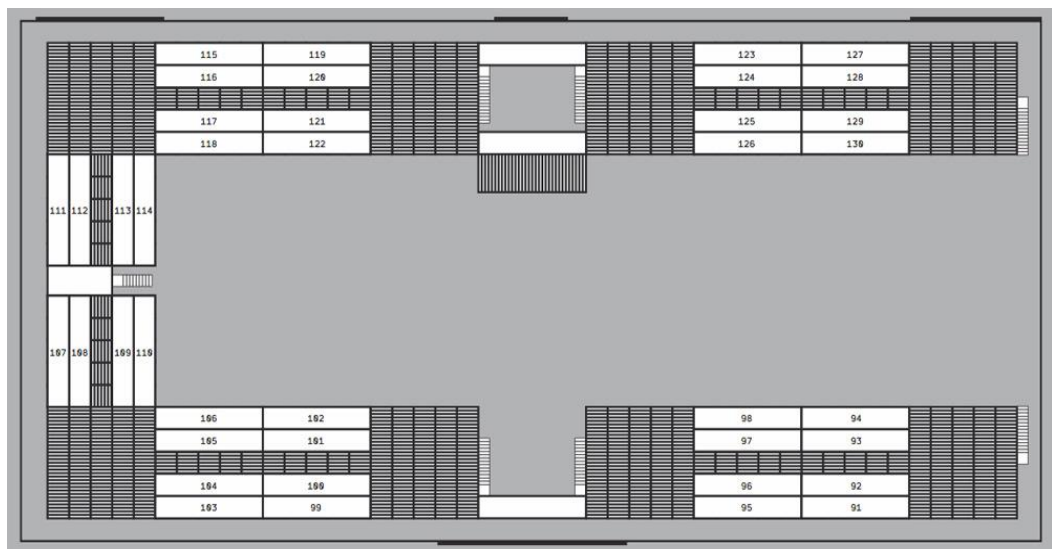




Fig.32: First floor plan Source:deezzen

Table 5: parameters of case study 2

Containers				
Strength	Sustainability	Durability	Climate change	Mobility
safety	Eco friendly	Maintenance	Weather	transportation
Container Architecture				
Structure	Sustainability	Maintenance	Cooling/heating	flexibility

3.3 Comparison Between the two Case Studies

Table 6: comparison table between the two case studies

Case Study	Urban Rigger	Box Park
Parameter of Analysis		
Function	Dormitory	Mall
Location	Copenhagen	Croydon, UK
Area	7,319 sq. feet	2,622 sqm
Architect	BIG, Bjarke Ingels Architects	BDP
Opening date	2016	2016
Structure	Steel and concrete floating base and containers insulated by an air-gel developed by NASA	steel frame roof canopy structure
Sustainability	Reusage of abundant containers and all containers are equipped with hydronic radiant floor panels and a heat recovery ventilation system	reusage of the shipping container as a building with providing natural light
Maintenance	presence near the ocean which will force them inspect the containers several times a year	rusting the container due to direct lightning
Cooling and Heating	renewable source provide energy necessary for the operation of the building and the air conditioning	patio heaters and air conditions
Flexibility	composition of basic modules made from the shipping containers and can be connected to form a composition of a residence and other services for it	Standard sizes of containers

After comparing between the case studies, the research will obtain more findings based on an online survey about potentials of containers in creating modular architectural spaces.

This survey will be composed of four questions and was given to students, architects, coworkers and volunteers.

The questions are classified as the following:

Question 1: Is it possible to have a city made from containers?

Question 2: Would you rather live in a normal apartment or in a container?

Question 3: In your opinion, what would be the worst part while being present in a container?

Question 4: If you have a container and want to transform it to an architecture space, would you rather transform it to: Apartment, retail shop, office space, or storage?

4. FINDINGS

According to the questionnaire done the responses and statistics are present in the charts below:

4.1 Question1: Is it possible to have a city made from containers?

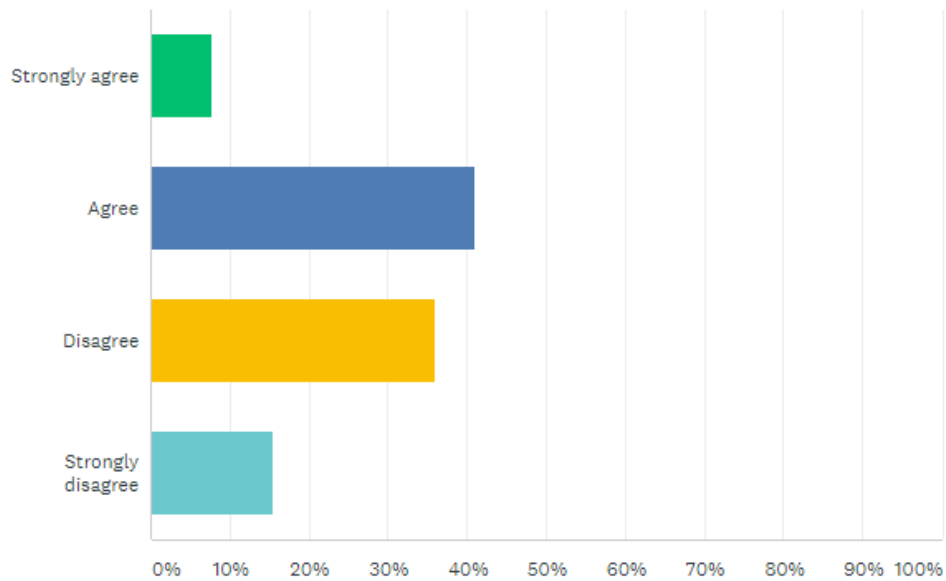


Fig.32: Chart showing the statistics of the obtained responses from the first question in the conducted survey.

Table 6: statistics of the obtained responses from the first question in the conducted survey.

ANSWER CHOICES	SCORE	RESPONSES	
✓ Strongly agree	1/1	7.69%	3
✓ Agree	1/1	41.03%	16
✓ Disagree	1/1	35.90%	14
✓ Strongly disagree	1/1	15.38%	6
TOTAL			39

4.2 Question 2: Would you rather live in a normal apartment or in a container?

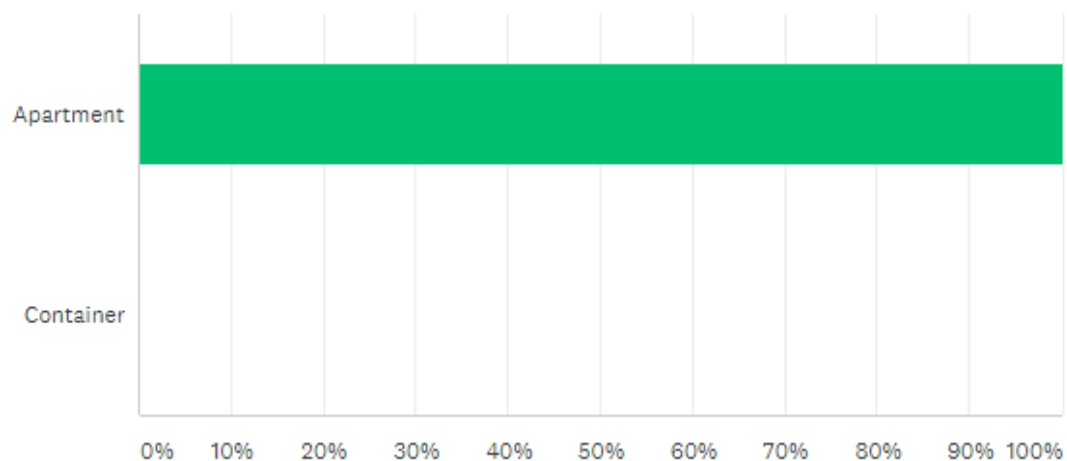


Fig.33: Chart showing the statistics of the obtained responses from the second question in the conducted survey

Table 7: statistics of the obtained responses from the second question in the conducted survey

ANSWER CHOICES	SCORE	RESPONSES	
✓ Apartment	1/1	100.00%	38
✓ Container	1/1	0.00%	0
TOTAL			38

4.3 Question 3: In your opinion, what would be the worst part while being present in a container?

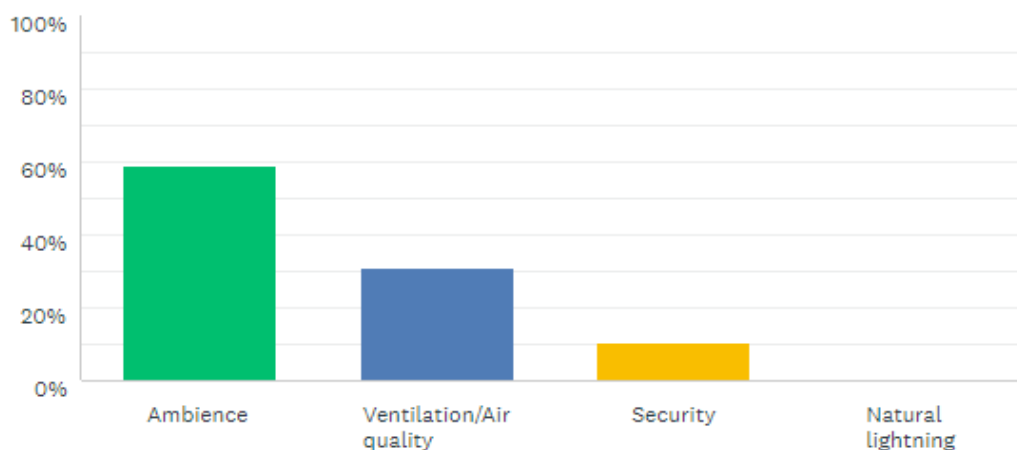


Fig.34: Chart showing the statistics of the obtained responses from the third question in the conducted survey

Table 8: statistics of the obtained responses from the third question in the conducted survey

ANSWER CHOICES	SCORE	RESPONSES	
✓ Ambience	1/1	58.97%	23
✓ Ventilation/Air quality	1/1	30.77%	12
✓ Security	1/1	10.26%	4
✓ Natural lightning	1/1	0.00%	0
TOTAL			39

4.4 Question 4: If you have a container and want to transform it to an architecture space, would you rather transform it to: Apartment, retail shop, office space, or storage?

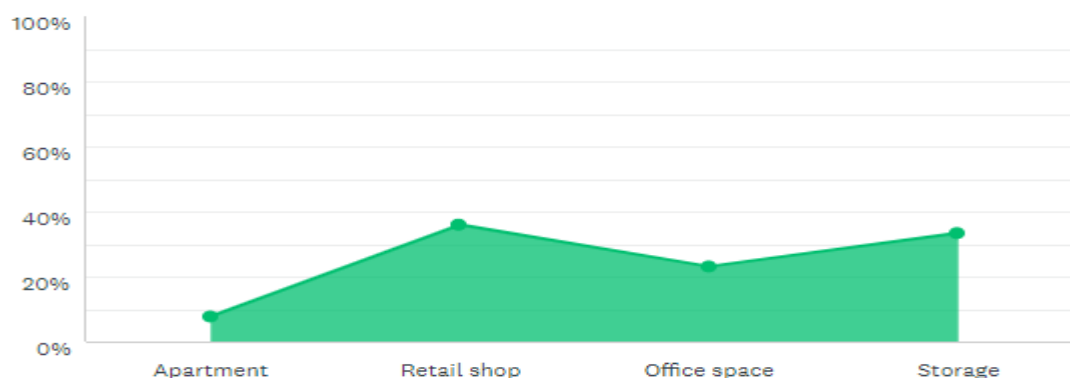


Fig. 35: Graph showing the statistics of the obtained results from the fourth question in the conducted survey.

Table 9: Statistics of the obtained responses from the fourth question in the conducted survey

▼ ✓ Apartment	1/1	7.69%	3
▼ ✓ Retail shop	1/1	35.90%	14
▼ ✓ Office space	1/1	23.08%	9
▼ ✓ Storage	1/1	33.33%	13
TOTAL			39

5. DISCUSSION

Based on the online survey that was done, 49% agreed that a city can be made from containers and 51% disagreed. Moreover, upon asking whether they prefer to live in an apartment or in a container, 100% chose to live in an apartment. The third question that was asked in the survey was stating the worst part while being present in a container, 59% were worried about the ambience, 31% were worried about ventilation and air quality, 10% were worried about their security and 0% were worried about the lightning. And finally concerning the transformation of a container to an architecture space, 7% chose an apartment, 36% chose to transform it to a retail shop, 23% chose to transform it to an office space, and 34% chose to transform it to a storage.

The aim of this paper is to explore the container architecture by identifying different ways of creating architecture spaces that hosts different functions and activities not only in micro view but also in macro which means in large scale. After doing the research and obtaining the results of the survey, we saw that many people don't know about the architecture of containers and how containers can be used as shown in the previous similar examples talked about in this paper. Moreover, the fact that a city can be built from containers and the fact that approximately half the number of people who did the survey agreed on it proves that containers can be used for macro view or as an urban element.

This verifies the aim of the study where the results shows that cities can be built with containers, and throughout this paper, the readers will have a clear view on which they can obtain a great architecture aspect in a container as if they are in a normal apartment without worrying about the ambience, ventilation, security or lightning.

6. CONCLUSION

The paper concludes that there are several design considerations that could be applied by architects and engineers to provide a good view for the containers and the usage of them.

- A- Urban planners should consider the usage of containers instead of concrete housing unit in this way the city will be more modular and the reuse of containers will obtain sustainability.
- B- Architects should provide several solutions for ventilation, air quality, security and lightning inside a container while designing it.
- C- Interior designers should consider designing the interior on it to obtain a welcoming ambience like any concrete architecture space.
- D- Engineers should consider introducing container housing units.
- E- People should give living in a container a try and don't judge a book by its cover
- F- Government should spread awareness about sustainability and reusing the shipping containers instead of throwing them away
- G- People should see the potentials of reusing containers that obtains proper design decisions and engineer solutions.

7. ACKNOWLEDGMENT

We would like to express our special thanks for all who participated in the online survey, our family and friends who supported us throughout writing this paper and shared their opinion with us. This paper changed a lot of what we think and gave us many new information that is fruitful for our future and our work. Thanks to our university for having such a course that gives such a great experience in different topics in architecture.

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